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Effects of bran on serum cholesterol, faecal mass, fat, bile acids and neutral sterols, and biliary lipids in patients with diverticular disease of the colon[1]

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SUMMARY Twenty-two patients with symptomatic diverticular disease of the colon were randomly allocated to control and high-fibre groups so that the long-term effect (up to 12 months) of bran on serum, faecal and biliary lipids could be studied. Even in cases of high initial values, faecal mass was increased by bran and the change was positively correlated with the change in dietary fibre. Faecal fat and dry weight were also increased. Faecal bile acids were initially slightly raised and were positively correlated with wet weight both off and on bran. The latter significantly decreased the excretion and concentration of bile acids, in particular the high initial values. The change in bile acids was not correlated with the change in dietary fibre or faecal wet weight. Sterol balance values indicated that the bran-induced decrease in faecal bile acids was associated with a lower cholesterol synthesis. Serum cholesterol decreased significantly in two hypercholesterolaemic individuals only. Correlations between different parameters revealed that the higher the initial level or the greater the drop in cholesterol synthesis, the greater the decrease in serum cholesterol. Bran had no effect on the biliary saturation of cholesterol. The percentage of biliary deoxycholate was negatively correlated with faecal mass (less so with faecal bile acid output) both before and during bran and was significantly decreased by bran. The percentage of cholic acid increased correspondingly and that of chenodeoxycholate remained unchanged. Faecal bile acids also indicated that the synthesis of the two primary bile acids was lowered by bran to the same degree.

It has been suggested that dietary fibre increases faecal bile acid excretion, leading to a fall in serum cholesterol (Mathur *et al.*, 1968; Trowell, 1972a, b). *In vitro* bile acids are actually bound by lignin (Eastwood and Girdwood, 1968) and many other vegetable fibres including alfalfa and pectin (Story and Kritchevsky, 1976). The latter precipitates bile acids from intestinal contents obtained after a test meal (Miettinen and Tarpila, 1976). *In vivo*, however, lignin is unable to increase faecal bile acid excretion (Eastwood and Hamilton, 1968; Heaton *et al.*, 1971), while cellulose, Metamucil, and pectin promote faecal elimination of cholesterol as bile acids resulting in a lowering of serum cholesterol (Forman *et al.*, 1968; Shurpalekar *et al.*, 1971; Stanley *et al.*, 1973; Durrington *et al.*, 1976; Miettinen and Tarpila, 1977). Dietary fibre may increase the bulk of the intestinal contents, making them colloidal, and thus sequestering and diluting bile acids. In addition, a shorter intestinal transit may decrease the absorption of bile salts in the distal ileum (Stanley *et al.*, 1973).

The results of previous studies on the effect of dietary bran on the excretion of faecal steroids vary. In some studies (Walters *et al.*, 1975) the dilution of faecal bile acids and neutral steroids has been established, while faecal excretion of these compounds is not consistently affected (Eastwood *et al.*, 1973; Findlay *et al.*, 1974). In most studies bran has no constant effect on serum cholesterol and triglycerides (Truswell and Kay, 1976), while functional colonic disorders and symptoms of patients with diverticular disease of the colon are usually but not consistently improved (Eastwood *et al.*, 1973; Painter and Burkitt, 1975; Brodribb and Humphreys, 1976; Soltoft *et al.*, 1976; Taylor and Duthie, 1976; Brodribb, 1977).

The present controlled study examined the

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effects of wheat bran on serum and biliary lipids, and on faecal steroids and stool composition in patients with symptomatic diverticular disease of the colon. Some preliminary results of the investigation have been presented earlier (Tarpila and Miettinen, 1975; Tarpila *et al.*, 1976).

Methods

PATIENTS

Twenty-two patients with diverticular disease of the colon were randomly allocated (Table 1) into fibre (cases 1-10) and control groups (cases 11-22). All the patients had symptoms (no rectal bleeding) which were scored from 0-2 according to severity, as revealed by questionnaires presented to the patients. As pain, constipation, diarrhoea, stool consistency, meteorism, and frequency of bowel movements were recorded the maximum score was 12. The fibre group scored 8·8 ± 0·8 and the controls 7·8 ± 0·9. The groups were matched for symptoms, number of colonic diverticula, sex, age, and body weight. Patients older than 65 years and those with other diseases such as uncompensated heart failure, severe coronary heart disease, manifest diabetes, and collagen diseases were excluded.

PROCEDURES

The two groups were advised to continue their previous dietary habits during the study, which was planned to last for 12 months. The fibre group was instructed to have six rusks (= 3·6 g of crude fibre specially prepared for the purpose from wheat bran) each day and 25 g of wheat bran (2·0 g of crude fibre). These instructions provided for an increase of 5·6 g in the daily crude fibre intake. The wheat bran used was a mixture of a coarse and fine bran. According to the producer (The Raisio Factories, Raisio, Finland) it contained 60% of the coarse bran (particle size 1120-1600 μm) and 40% of the fine bran (particle size 400-500 μm); the water-holding capacity of the mixture was 2·95 g/g and the cation exchange capacity 0·35 mEq of Na^+/g. The control group was advised to consume six low-fibre rusks (0·5 g of crude fibre). The instructions were given continuously and for this purpose the patients visited the outpatient department every sixth week. Dietary interviews and records were obtained by a trained dietician (L.M.) at the beginning of the study and after six and 12 months. The fasting blood samples for serum cholesterol and triglyceride determinations were obtained three times before the study and every sixth week during

Table 1 *Faecal composition in patients with diverticular disease of colon before and six and 12 months after adding bran to diet*

Case	*ge (yr)*	*Weight (kg)*	*Height (cm)*	*Sex*	*Crude fibre intake (g/d)*			*Faecal mass (g/d)*			*Faecal steroids (mg/day)*						*Sterol balance (mg/d)*		
											Bile acids			*Neutral sterols*					
					0	*6*	*12*	*0*	*6*	*12*	*0*	*6*	*12*	*0*	*6*	*12*	*0*	*6*	*12*
Fibre group																			
1	46	56	160	F	2·4	5·9	—	135	183	—	441	246	—	630	544	—	− 748	− 546	—
2	53	60	162	F	4·7	7·3	7·2	202	235	167	581	231	179	828	865	625	−1093	− 732	− 392
3	51	76	172	M	5·2	10·9	10·0	228	378	302	556	465	312	1323	2074	642	−1416	−2076	− 491
4	51	49	156	F	4·6	10·6	7·7	152	235	142	251	179	89	866	900	527	− 714	− 671	− 203
5	47	84	182	M	6·6	12·6	13·6	294	429	443	403	382	354	1585	1105	332	−1267	− 905	− 243
6	51	74	169	M	5·1	5·3	7·9	309	235	241	353	161	243	983	796	547	−1087	− 838	− 554
7	64	103	178	M	6·1	8·5	—	352	245	—	371	452	—	914	751	—	− 905	− 893	—
8	61	61	162	F	3·5	7·6	8·1	227	263	294	450	492	263	396	842	570	− 535	−1119	− 585
9	47	90	178	M	2·2	7·0	—	195	295	—	1132	800	—	337	469	—	−1315	− 704	—
10	35	49	167	F	3·2	6·1	—	59	228	—	207	433	—	300	488	—	− 40	− 422	—
Mean	50·5	70·1	169		4·4	8·2	9·1	215	272	265	475	384	240	816	883	541	− 912	− 754	− 411
±SE	±8·1	±18·4	±3		±0·5	±0·8	±1·0	±28	±24	±44	±82	±61	±39	±133	±147	±46	± 131	± 103	± 85
Control group																			
11	63	67	163	M	3·8	4·4	3·4	232	163	112	323	440	192	573	564	484	− 210	− 353	− 61
12	64	88	173	M	2·8	3·6	4·6	133	212	188	160	213	221	798	656	490	− 575	− 389	− 135
13	59	65	166	F	2·3	2·6	2·4	77	81	68	92	102	98	698	1087	801	− 510	− 919	− 644
14	49	79	156	F	1·9	2·0	2·6	284	180	337	497	407	476	1681	1373	966	−1914	−1418	− 983
15	43	51	156	F	3·4	4·5	5·5	109	150	—	206	191	—	265	511	—	− 84	− 315	—
16	39	88	179	M	4·1	—	3·2	271	—	305	623	—	854	975	—	1088	− 973	—	−1498
17	35	54	161	F	1·7	2·2	3·2	198	125	202	343	266	291	473	597	339	− 555	− 725	− 468
18	57	62	166	M	6·4	4·4	6·0	131	80	120	393	238	498	408	414	701	− 567	− 413	− 922
19	54	64	170	M	5·2	4·4	5·2	132	146	102	522	293	139	597	561	799	− 418	− 158	− 384
20	55	53	163	F	3·5	5·2	—	210	283	—	330	398	—	609	368	—	− 707	− 458	—
21	55	80	172	M	4·7	6·3	—	130	131	—	347	706	—	1010	948	—	−1132	−1274	—
22	43	75	160	F	2·5	2·6	—	95	199	—	125	270	—	710	857	—	− 597	− 689	—
Mean	52·2	68·7	165		3·5	3·8	4·0	167	155	179	330	320	346	733	697	709	− 687	− 620	− 637
±SE	±10·1	±13·2	±2		±0·4	±0·4	±0·4	±20	±19	±35	±48	±49	±89	±106	±93	±91	± 139	± 156	± 170

the study. Three-day stool collections were obtained before the study and after six and 12 months. For this purpose the patients received unabsorbable markers, Cr_2O_3 (600 mg/day) and ^{3}H-β-sitosterol (0·5 μCi/day) starting seven days before the collections. The intake of the markers was checked from the number of tablets returned after the collection. Seven-day food records were kept, starting five days before each stool collection. Duodenal bile was aspirated after a 12-hour fast, using cholecystokinin to provoke gall-bladder contraction. The samples were obtained from five subjects before and during bran and from four additional cases during bran only. The corresponding numbers of cases sampled in the control group were seven and three.

ANALYTICAL METHODS

Dietary intake of calories, fat, crude fibre, and cholesterol were calculated as averages from the seven-day food records using standard tables for the composition of different food ingredients. Serum cholesterol and triglycerides were determined with the automated methods of our hospital laboratory. Faecal fat was measured according to the method of van de Kamer *et al.* (1949). Total faecal bile acids and neutral sterols were measured using gas chromatography on a nonpolar DC-560 column (Grundy *et al.*, 1965; Miettinen *et al.*, 1965) which was also applied to the measurement of biliary cholesterol and bile acids. Separation of individual biliary bile acids were obtained, however, on a polar (NGS) column. The combination of gas chromatographic analyses on the nonpolar and polar columns permitted the quantitative determination of faecal intact cholic and chenodeoxycholic acid and faecal bile acids originating either from cholic acid or chenodeoxycholic acid. The faecal bile acids of chenodeoxycholic acid origin were measured as follows: lithocholate, isolithocholate and ketonic derivatives were measured on the DC-560 column, and ursodeoxycholate and intact chenodeoxycholate were determined on the NGS column. Intact cholate was measured on the NGS column, while the faecal bile acids of cholic acid origin were obtained as the difference between the total faecal bile acids and those of chenodeoxycholic acid origin. Biliary phospholipids were measured according to the method of Bartlett (1959). The recovery of the labelled β-sitosterol in stools tended to be less than 100% compared with Cr_2O_3 recovery. As this could have been due to losses of the sterol during the intestinal passage, a corresponding correction was made for the faecal neutral sterols of cholesterol origin (Grundy *et al.*, 1968). Sterol balance was obtained as the difference between the dietary cholesterol and the sum of faecal bile acids and neutral sterols of cholesterol origin. The faecal flow was measured from the Cr_2O_3 flow (Bolin *et al.*, 1952).

Results

FIBRE INTAKE

Initial intake of dietary fibre was similar in both

Table 2 *Dietary characteristics, body weight, serum lipids, stool composition, and biliary lipids in patients with colonic diverticulosis on control and high fibre diet (mean ± SE)*

Parameter	Control group (months on trial)			Fibre group (months on trial)		
	0	6	12	0	6	12
Calorie intake (kcal/day)	1929 ± 194	1868 ± 413	2349 ± 225	1806 ± 126	1797 ± 218	2293 ± 190
Cholesterol intake (mg/day)	376 ± 54	382 ± 83	418 ± 59	378 ± 48	377 ± 64	374 ± 46
Fat intake (g/day)	81 ± 11	83 ± 18	101 ± 17	76 ± 10	92 ± 12	96 ± 9
Fibre intake (g/day)	3·5 ± 0·4	3·8 ± 0·4	4·0 ± 0·4	4·4 ± 0·5	8·2 ± 0·8*	9·1 ± 1·0*
Body weight (kg)	68·3 ± 3·8	69·6 ± 3·7	68·7 ± 4·5	70·2 ± 5·8	72·0 ± 5·5*	68·5 ± 4·7
Serum cholesterol (mmol/l)	6·7 ± 0·4		6·6 ± 0·4	7·2 ± 0·6		7·0 ± 0·4
Serum triglycerides (mmol/l)	1·28 ± 0·27		1·18 ± 0·20	1·40 ± 0·13		1·49 ± 0·15
Faecal mass (g/day)	167 ± 20	155 ± 19	179 ± 35	215 ± 28	272 ± 24*†	265 ± 44
Faecal dry weight (g/day)	33 ± 4	29 ± 2	37 ± 6	38 ± 4	55 ± 5*†	47 ± 7
Faecal fat (g/day)	5·3 ± 1·1	4·2 ± 0·5	5·5 ± 1·4	4·2 ± 0·7	6·9 ± 1·4*	5·0 ± 0·9
Faecal bile acids (mg/day)	330 ± 48	320 ± 49	346 ± 89	475 ± 82	384 ± 61	240 ± 39*
Faecal neutral sterols (mg/day)	580 ± 92	538 ± 92	693 ± 136	617 ± 112	800 ± 121	614 ± 39
Sterol balance (mg/day)	−687 ± 139	−647 ± 156	−637 ± 170	−912 ± 131	−816 ± 103	−411 ± 85*
Faecal cheno‡	39 ± 3	40 ± 3	38 ± 3	39 ± 1	41 ± 1	45 ± 4
Faecal cholic acid§	10·0 ± 2·8	8·0 ± 2·4	2·1 ± 2·1	4·3 ± 1·6	5·1 ± 1·7	2·4 ± 0·8
Faecal cheno§	1·0 ± 0·8	0·8 ± 0·5	0·2 ± 0·2	5·1 ± 2·5	3·3 ± 1·4	1·4 ± 0·6
Biliary cholesterol (M%)	10 ± 3		8 ± 1	9 ± 3		9 ± 1
Biliary phospholipids (M%)	20 ± 3		22 ± 2	22 ± 2		21 ± 1
Biliary bile acids (M%)	70 ± 4		69 ± 2	69 ± 4		71 ± 2
Biliary cheno (%)	38 ± 5		40 ± 4	44 ± 2		42 ± 3
Biliary cholic acid (%)	37 ± 4		38 ± 5	42 ± 2		48 ± 3*
Biliary deoxy (%)	25 ± 6		22 ± 7	14 ± 4		10 ± 3*

*Statistically significant change ($P < 0·05$). †Different from controls ($P < 0·05$). ‡Percentage of faecal bile acids derived from chenodeoxycholic acid. §Amount of intact cholic acid or chenodeoxycholic acid, % of total faecal bile acids.

groups (Table 1). In the fibre group it increased from the initial mean of 4·4 ± 0·5 g/day to 8·2 ± 0·8 g/day at six months (P < 0·001) and to 9·1 g/day at 12 months (P < 0·001), while in the control group the respective values (3·5 ± 0·5, 3·8 ± 0·4 and 4·0 ± 0·4 g/day) did not change significantly. Thus, the fibre intake had increased significantly more (P < 0·001) in the experimental than in the control group. It should be noted that the expected increase was 5·6 g/day and that the actual increase ranged from 0·2 to 7·0 g/day, indicating that over long periods the patients were unable to follow the instructions adequately.

BODY WEIGHT

No significant changes (Table 2) could be detected in calorie and fat consumption or in cholesterol intake in the two groups during the study. The body weight of the fibre group had significantly increased at six months (+1·8 ± 0·7 kg), but not at 12 months. The changes did not, however, differ from those in the controls.

SERUM LIPIDS

The fibre diet had no consistent serum cholesterol-lowering effect (Table 2). However, the serum cholesterol level decreased significantly in two of the four hypercholesterolaemic (> 7·5 mmol/l) patients in the fibre group but not in any of the five hypercholesterolaemic controls. Furthermore, the change in the serum cholesterol of the fibre group was negatively correlated ($r = -0{\cdot}782$) with the initial values, while in the controls this correlation did not reach a significant level ($r = -0{\cdot}304$), as if the bran had normalised raised serum cholesterol levels (Fig. 1). Serum triglycerides remained at the initial level.

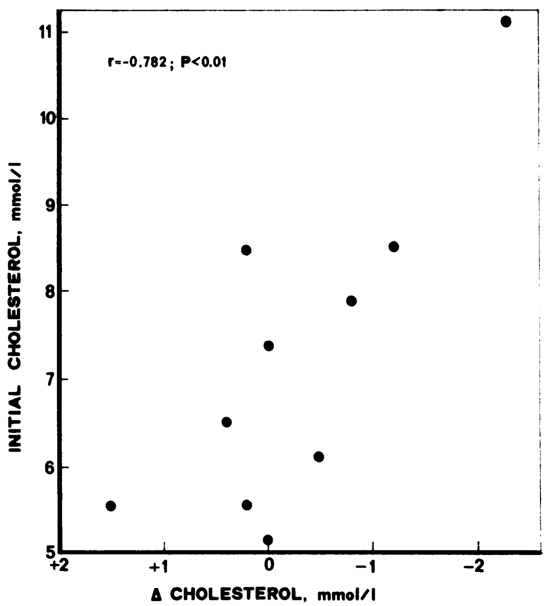

Fig. 1 *Correlation of the bran-induced change in serum cholesterol with the initial cholesterol values in the fibre group. The corresponding r-value in the control group was −0·304 (not significant).*

FAECAL WEIGHT AND FAT

Faecal wet weight, dry weight, and fat increased at six months in the fibre group but not in the control group (Tables 1 and 2). The change in the wet weight was negatively correlated with the initial values ($r = -0{\cdot}646$). After 12 months the values were only insignificantly raised, though the average intake of the dietary fibre was still 4·1 g/day higher than initially. Changes in the fibre intake were significantly correlated with those in the wet weight ($r = 0{\cdot}738$) and dry weight ($r = 0{\cdot}551$) in the fibre group but not in the controls (respective r values 0·378 and −0·201).

FAECAL BILE ACIDS

The initial faecal bile acid excretion was the same in both groups—namely, 475 ± 82 mg/day in the fibre group and 330 ± 48 mg/day in the control group (Table 1). The average bile acid output of these patients was 396 ± 47 mg/day or 5·7 ± 0·6 mg/kg/day and is higher than in our normal control subjects on a solid food diet (238 ± 25 mg/day or 3·8 ± 0·2 mg/kg/day).

The fibre diet significantly reduced the faecal bile acid output (see Figs. 2 and 3), particularly after 12 months on the diet (< 0·02), while in the control group no consistent change was recorded (Table 1). This was associated with a significantly greater decrease in faecal bile acid concentration in the fibre group (from 2·6 ± 0·4 to 1·1 ± 0·1 mg/g) than in the control group (from 2·0 ± 0·3 mg/g to 2·1 ± 0·3 mg/g). Furthermore, the initial bile acid concentration was negatively correlated with the change in the concentration of the fibre group but not of the control group (Fig. 4). In addition, the changes in faecal bile acid excretion were negatively correlated with the initial values in the fibre group, while in the controls this correlation was not significant (Fig. 3). Thus, the bran actually normalised abnormal bile acid output, reduced the initially high excretion in particular, and lowered faecal bile acid concentration, especially when it was initially high.

Even though faecal bile acids were significantly correlated with the wet stool weight on both the control and the fibre diets (Fig. 2) no correlation was found between the changes in the faecal mass

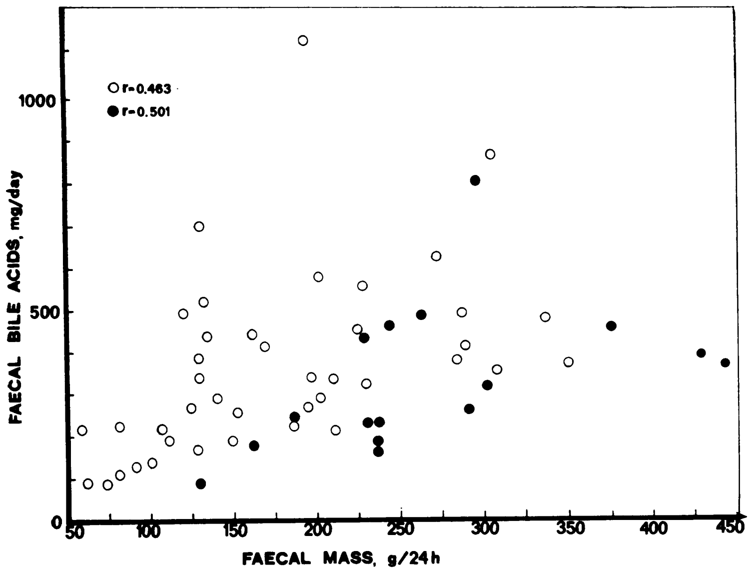

Fig. 2 *Correlation between faecal mass and bile acids;* ○ = *initial values of the fibre group and all values of the control group;* ● = *values on fibre diet.*

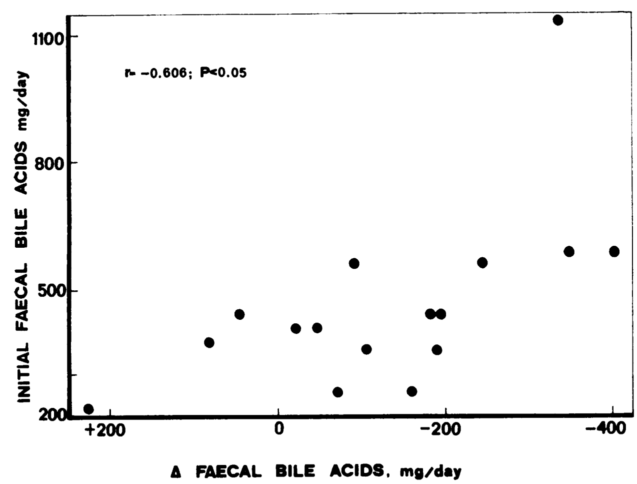

Fig. 3 *Correlation of the bran-induced change in faecal bile acids with the initial values. The corresponding r-value in the control group was* $-0{\cdot}249$ (*not significant*).

and bile acids caused by bran ($r = 0{\cdot}236$). The bile acids and dietary fibre ($r = 0{\cdot}131$), and their respective changes ($r = 0{\cdot}157$), were also not correlated with each other.

FAECAL NEUTRAL STEROLS AND STEROL BALANCE

The faecal neutral sterol excretion, which was not correlated with dietary cholesterol or fat intake, decreased insignificantly during the fibre diet (Table 1). Faecal neutral sterols were not correlated with the fibre intake or faecal bile acids but showed a positive correlation with faecal fat ($r = 0{\cdot}320$; $P < 0{\cdot}05$).

The sterol balance value was significantly lower in the fibre group than in the control group after 12 months, indicating that the reduced production of bile acids was associated with a decreased cholesterol synthesis. Furthermore, the changes in the serum cholesterol levels were significantly correlated ($r = 0{\cdot}511$) with those in the sterol balance values (Fig. 5) of the fibre group but not of the control group ($r = -0{\cdot}026$).

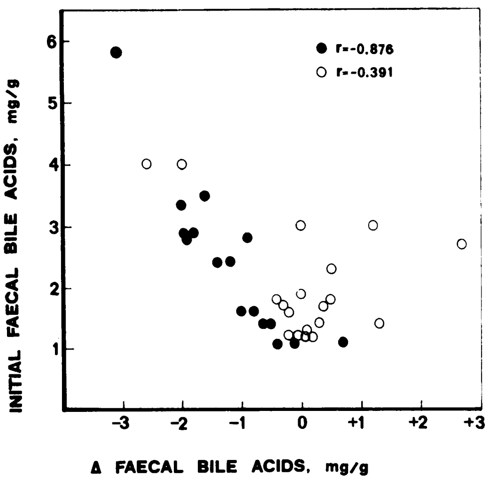

Fig. 4 *Correlation of the bran-induced change in faecal bile acid concentration with the initial values;* ○ = *values of the control group;* ● = *values of the fibre group.*

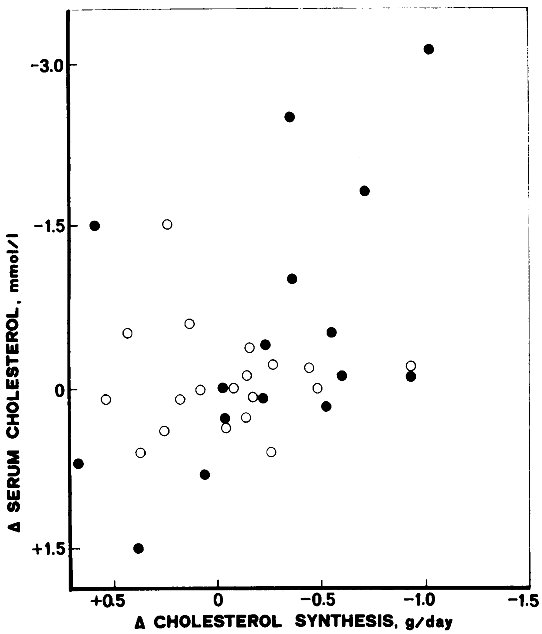

Fig. 5 *Correlation between the bran-induced changes in cholesterol synthesis and serum cholesterol.* ○ = *values of the control group,* $r = -0{\cdot}026$; ● = *values of the fibre group,* $r = 0{\cdot}511$.

DUODENAL COMPOSITION

The degree of biliary saturation of cholesterol did not change in the high fibre group or in the control group. However, the relative amount of deoxycholic acid, which was fairly low initially in the fibre group, decreased further on the fibre diet and this decrease was greater than that in the controls (Table 2). This was associated with a corresponding increase in cholic acid, while the amount of chenodeoxycholate showed no consistent change.

It is interesting to note that the faecal mass was negatively correlated with the percentage of biliary deoxycholate and positively with that of cholic acid on both the high and the low fibre diet (Fig. 6). The correlation of total faecal bile acids with the percentage of biliary deoxycholate was significant only during the fibre diet ($r = 0{\cdot}769$). Biliary and faecal percentages of bile acids of chenodeoxycholic acid origin were the same and remained unaffected by the fibre diet. Thus, the synthesis of the two primary bile acids had been equally reduced by the bran.

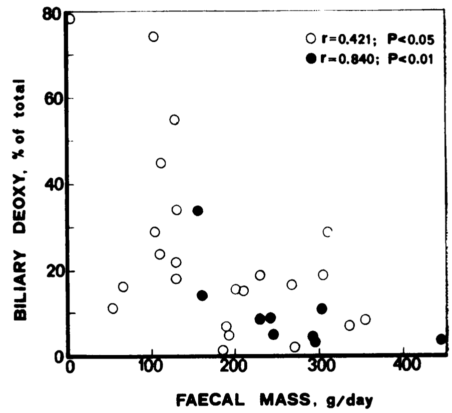

Fig. 6 *Correlation of faecal mass with percentage of biliary deoxycholate on low* (○) *and high* (●) *fibre diet.*

Discussion

In the present controlled study attention was focused on the long-term effects of dietary bran on serum lipids and biliary and faecal composition in patients with symptomatic diverticular disease of the colon, an ailment believed to be caused by a long-lasting deficiency of dietary fibre (Painter and Burkitt, 1975). The clinical, functional, bacteriological, and other biochemical findings will be reported elsewhere.

The presence of symptoms, diarrhoeal bouts in particular, was apparently accounted for the fact that some of the initial faecal data deviated from the normal values or from those found in non-symptomatic patients. Accordingly, the response to bran may also have been different, although, as in other studies (Findlay *et al.*, 1974; Brodribb and Humphreys, 1976; Taylor and Duthie, 1976; Brodribb, 1977), the symptoms clearly abated during the bran period. The initial faecal wet and dry weights exceeded those reported recently in uncomplicated diverticular disease of the colon (Findlay *et al.*, 1974; Brodribb and Humphreys, 1976) and the wet weight is high by normal standards. Faecal bile acids, which were normal in the series studied by Findlay *et al.* (1974), were higher than in our normal subjects. Of the 11 diverticular patients whose faecal bile acids exceeded the normal upper limit (Miettinen, 1973) (5·6 mg/kg/day), eight had frequent diarrhoeal and four constipated bouts, while in those with normal faecal bile acids the respective figures were four and seven. In none of the cases was the diarrhoea continuous, suggesting that primary ileal bile acid malabsorption (Hess-Thaysen and Pedersen, 1976) was not likely to be the cause of the slightly increased faecal bile acids. A positive correlation between the latter and faecal wet weight suggests, however, that the bile acids contribute to diarrhoea in diverticular disease. Enhanced intestinal motility, known to increase faecal bile acids slightly (Meihoff and Kern, 1968), seems the most likely cause of the slight bile acid malabsorption and associated diarrhoeal bouts.

Bran further increased faecal wet weight in most of the patients despite its initially high value. This increase, found by others in normal subjects (Williams and Olmsted, 1936; Southgate and Durnin, 1970; Eastwood *et al.*, 1973; Findlay *et al.*, 1974; Southgate *et al.*, 1976) and in diverticular patients with low initial faecal wet weight (Brodribb and Humphreys, 1976; Findlay *et al.*, 1974; Taylor and Duthie, 1976), is correlated with several factors. A change in bran intake, the initial wet weight, and initial amount of and change in bile acid output were the most important of these in the present series. The positive correlation between the changes in the fibre intake and faecal mass indicates that the increase in mass would have been even higher if the patients had increased their fibre intake according to the instructions. The positive correlation between the faecal mass and bile acids indicates that the bran-induced decrease in bile acids significantly counteracted the bran-induced increase in faecal mass. In addition, intestinal bacteria degrade some components of bran (Williams and Olmsted, 1936; Southgate and Durnin, 1970; Southgate *et al.*, 1976). This could have decreased the faecal dry weight after microbial adaptation in the long-term—that is, within six to 12 months of the start of the trial.

Previous studies have revealed insignificant changes in both faecal bile acid excretion and faecal bile acid concentration by bran in patients with diverticular disease of the colon (Findlay *et al.*, 1974). In the present study these two parameters were significantly reduced by bran. The mechanism of the decrease in faecal bile acids is unclear but an altered ileal absorption in the presence of bulky intestinal contents, most likely *via* normalisation of small bowel transit, seems the most likely cause of this. The lack of a significant correlation between the decrease in bile acids and the increase in dietary fibre also suggested that the bran-induced decrease in elimination of bile acids is indirectly associated with the increase in bran intake.

In contrast with bile acids, fatty acid excretion was increased by bran, a finding recorded in other studies for normal subjects (Southgate and Durnin, 1970; Southgate *et al.*, 1976). The reason for the slight fat malabsorption is unknown. Faecal fatty acid composition differs from that in the diet (Southgate *et al.*, 1976), suggesting that endogenous and bacterial fatty acids contribute to slightly reduced absorption of dietary fat.

As cholesterol absorption was not measured in the present series, the cause of the tendency to less neutral sterol excretion during bran remained unknown. The recovery of labelled sitosterol was the same during the two periods, indicating that bacterial degradation of sterols was hardly affected. Furthermore, the relative amounts of the secondary neutral steroids, coprostanol and coprostanone, were not changed by bran either.

Despite slight bile acid malabsorption, the initial serum cholesterol level was surprisingly high in the patients in the present series. This indicates that the synthesis of cholesterol was high. The sterol balance value (789 mg/day or 11·4 mg/kg/day) actually shows the synthesis to be at a normal high level considering the quite high cholesterol intake (377 mg/day or 5·4 mg/kg/day). The finding that bran had no consistent effect on serum cholesterol agrees with many other studies (Truswell and Kay, 1976) and indicates that, although in some patients with hypercholesterolaemia a slight reduction in the serum cholesterol level can occasionally be obtained, in general bran is not an effective hypocholesterolaemic agent.

However, bran significantly changed the sterol balance value, indicating that the bran-induced decrease in faecal bile acids was actually associated with a reduced cholesterol synthesis. Restoration of intact enterohepatic circulation of bile acids—for example, discontinuation of cholestyramine treatment or correction of ileal by-pass—is usually associated with a decrease in the high cholesterol synthesis and an increase in serum cholesterol (cf. Miettinen, 1973). If bran actually improved ileal bile acid absorption the enhanced portal flux of bile acids to the liver could have inhibited cholesterol synthesis. The latter was apparently balanced by faecal elimination of cholesterol, the mean serum cholesterol remaining unaltered. However, individual changes in serum cholesterol were recorded and it was found that the higher the decrease in synthesis the higher the fall in serum cholesterol (see Fig. 4). Thus, in contrast to what has been generally believed, the influence of bran on serum cholesterol, whenever recorded, seems to be that it decreases its level by reducing cholesterol synthesis and elimination, and not by first enhancing elimination (impaired cholesterol and bile acid absorption) and stimulating synthesis second. Accordingly, the effect of bran differs from that of some other fibres—for example, cellulose, Metamucil, and pectin—which enhance cholesterol elimination as faecal bile acids, reduce serum cholesterol, and increase cholesterol synthesis (Forman *et al.*, 1968; Shurpalekar *et al.*, 1971; Stanley *et al.*, 1973; Durrington *et al.*, 1976; Miettinen and Tarpila, 1977).

In agreement with the findings of Pomare *et al.* (1973, 1976), biliary cholesterol saturation was not consistently normalised by bran. Initially, supersaturated bile tended to become less saturated but at the end of the trial about half of the subjects had supersaturated bile in both groups. Thus, even though cholesterol synthesis had decreased and bile acid absorption probably improved, the biliary composition was not normalised. A decrease in supersaturation has been found when the markedly increased synthesis in obese patients is lessened by weight reduction (Bennion and Grundy, 1975).

As others have found (Pomare *et al.*, 1973; 1976), bran significantly decreased biliary deoxycholate but, in contrast to earlier findings, it increased the biliary cholate but not the chenodeoxycholate content. That the synthesis of the two primary bile acids had actually decreased similarly was also indicated by the unaltered relative contribution of the two bile acids to faecal bile acids both before and during bran.

A negative correlation between the biliary percentage of deoxycholate and the faecal mass before and during bran, and a less significant correlation with the corresponding faecal bile acid values, suggest that faecal mass influenced the formation and/or absorption of deoxycholate. If the bran-induced decrease in faecal bile acids was actually a consequence of improved ileal bile acid absorption, then the ileal absorption of deoxycholate and its biliary content should have increased. As the latter decreased, the large colonic content, particularly in the presence of bran, apparently trapped deoxycholate effectively and was obviously the major reason for its decrease in the bile. Faecal analysis showed that some intact cholate was present but its amount was not related to the faecal mass and was not consistently altered by the fibre diet, suggesting that the bacterial production of deoxycholate was poorly correlated with the biliary deoxycholate. This does not exclude the possibility that deoxycholate production had decreased in the proximal and increased in the distal colon. Many diarrhoeal states are known to be associated with decreased biliary deoxycholate content, ileal dysfunction being one of the most potent aetiological factors (cf. Miettinen, 1973).

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Note added to proof Recalculation of the data by Raymond *et al.* (*Journal of Clinical Investigation* (1977) **60**, 1429) revealed that in agreement with the present findings the changes in faecal bile acids caused by a high fibre diet were negatively correlated ($r = -0{\cdot}661$; n 12; $P < 0{\cdot}05$) with the initial bile acid values.